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ENVIRONMENTAL RESEARCH

RESEARCH AND TECHNOLOGY BRANCH

RESEARCH NEEDS

1990-1995

November 1989



Environment
Ontario

Jim Bradley, Minister



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RESEARCH AND TECHNOLOGY BRANCH
ENVIRONMENTAL RESEARCH PROGRAM

R E S E A R C H N E E D S

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PREFACE

For over a decade, the Ontario Ministry of the Environment has encouraged excellence in environmental research through its successful and well respected Environmental Research Program. The Research Advisory Committee has supported close to 500 environmental research projects through grants and contracts to universities, consultants and other research institutions.

This document has been prepared under the guidance of the Research Advisory Committee with advice and input from the various Branches and Regions of the Ministry. It summarizes the medium-term (approximately 5-year) needs of the Ministry in the following research areas - Air Quality (AR), Water Quality (WA), Liquid and Solid Waste (LS), Analytical Method Development (AN), Environmental Socio-Economic Research (SE). Additionally, in 1989, a new area - Multimedia Contaminants and Biotechnology Research (MM) was introduced in order to deal with issues which cross medium boundaries in significant measure, as well as address risk identification and assessment, exposure assessment and toxicology.

The approach used in this document is new. This is the first time that a five-year needs projection for research has been made. Future editions of "Research Needs" will incorporate refinements as required to maintain the five-year needs current with the major programs and initiatives of the Ministry, as well as provide an annual research focus into problems or issues of immediate concern.

The research needs are presented hierarchically. Research areas are divided into research "categories" which are further divided into "issues". Specific research "needs" occur as the most detailed tier of this hierarchy.

"Categories" represent fields within the research area, and "issues" describe problems within the category. Finally, the "needs" provide a more detailed description of the scope of projects envisaged within an issue. Issues which are of immediate concern in 1990/91 are indicated at the beginning of each section. However, the necessarily limited listing of needs is not intended to restrict the submission of proposals. Proposed research based on new ideas is encouraged.

The purpose of the document is to assist researchers in the application process. Information relating to the application

procedure is available from:

Research and Technology Branch
Ontario Ministry of the Environment
135 St. Clair Avenue West, 9th Floor
Toronto, Ontario
M4V 1P5

Attention: Manager, Research Coordination

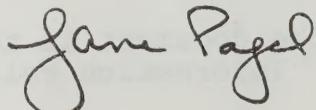
Telephone: (416) 323-4574

The 1990 deadline for the submission of proposals is January 15. It is possible that there will be a second deadline for proposal submissions in June should additional funds become available; however, it is advisable to contact the Branch to confirm this.

Proposals are evaluated on the basis of scientific merit and relevance to the Ministry needs and priorities. An important consideration is the availability of funding which is affected by budget constraints. Successful applicants will be required to enter into an agreement with the Ministry, and will be required to submit interim and final reports. Investigators will also be expected to present their findings at the annual Environmental Research Technology Transfer Conference usually held in late November. (Any costs associated with attendance at the Conference should be included in the proposal.)

For the information of applicants, some statistics on the 1989-90 rate of approval of proposals in each of the Research Areas, and the mean and range of the level of funding is included in the Appendix. Also, applicants can help to improve the usefulness of "Research Needs" by completing and returning a questionnaire which appears as the last page of this volume.

We welcome your contribution and suggestions for improvement to the Environmental Research Program.



Jane E. Pagel
Director
Research and Technology Branch

AIR QUALITY RESEARCH NEEDS

AIR QUALITY RESEARCH

The Air Quality Research Needs Document reflects the Ministry's mandate to protect the environment and human health, specifically as it is related to air pollution. The current research requirements are grouped under five categories, seven issues, and thirty-two needs. As one might reasonably expect, many of these entries are inter-related.

The five categories fall into two groups: primary and ancillary. The former includes the three basic components in the understanding of air pollution, namely, the environmental impacts/receptor (contaminant effects/toxicology/fates), the source (sources/inventories), and the intermediate processes (atmospheric processes) between the source and receptor. The latter includes abatement (control and remedial technology) at the source and receptor, and sampling (instrument development and application), which is necessary for source, receptor and process studies.

Each category is broken down into issues which define the area of research more concretely, e.g. contaminant effects into human, ecosystem, and phytotoxicology; and sources into industrial/commercial, stationary/domestic, and mobile sources.

Under each issue, particular research needs are listed. These needs are meant to provide general rather than specific guidance to prospective applicants. Because of the nature of the categories and issues, many of the research needs can be linked to issues other than the one under which they are grouped. Also, atmospheric research is not independent of other environmental disciplines, readers are therefore encouraged to look at other research areas cross-referenced at the bottom of each issue page.

AIR QUALITY RESEARCH
Issues of Immediate Concern

ISSUE:

- AR01 The Impact of Air Pollution on Ecosystems
- AR04 Industrial/Commercial Emissions
- AR05 Stationary Domestic Sources and Mobile Sources
- AR06 Monitoring Capability for Air Pollutants
- AR07 New Control Technology, Devices and Processes

SUMMARY OF AIR QUALITY RESEARCH ISSUES

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
<u>AIR QUALITY</u>			
Contaminant Effects/ Toxicology/Fates	AR01 The impact of air pollution on eco-systems. AR02 Physical and chemical processes involved in atmospheric transport of toxics, and acid rain.	8 9	WA18/37 WA20/39 SE01/98 WA10/29 WA19/38 LS03/55 AN15/87 SE02/100 SE06/104
Atmospheric Processes (including Source-Receptor Links)	AR03 Improved emergency response capability.	10	AR06/13
Sources/Inventories	AR04 Industrial/commercial emissions. AR05 Stationary domestic sources and mobile sources.	11 12	LS03/55 AN16/88 SE02/100 SE02/100
Instrument Development and Application	AR06 Monitoring capability for air pollutants.	13	WA04/23 WA07/26 LS03/55 LS11/63 AN16/88
Control and Remedial Technology	AR07 New control technology, devices and processes.	14	SE02/100 SE04/102

AIR QUALITY RESEARCH: CONTAMINANT EFFECTS/TOXICOLOGY/FATES

ISSUE: AR01

The impact of air pollution on ecosystems.

Type of Research Needed:*

- Studies of the accumulation and environmental pathways of toxic substances near point, area and mobile sources, and on a regional scale with particular reference to the Great Lakes Basin; e.g., atmospheric-terrestrial and aquatic interactions as they relate to movement and fate of toxic substances in environmental media.
- Investigation of impact of sulphur and nitrogen based acids from the atmosphere due to Long Range Transport of Air Pollutants.
- Determination of which air contaminants are having direct or indirect impact on human and animal life e.g. global warming, ozone depletion, health risk.
- Assessment of the effect of air releases of persistent chemicals on stratospheric ozone and global warming.
- Development/screening of invertebrates for biological indicators of environmental contaminants.
- Determination of the physiological pathways by which pollutants enter plants.
- Study of the interaction between plant diseases and various pollutants to determine the important parameters which affect the response of the plant.
- Assessment of the accumulation of various pollutants on vegetation, as well as background and toxic levels of pollutants in soils and vegetation.
- Development of vegetation monitors for environmental contaminants of interest.

*See Also:

- Water Quality Research: Contaminant Fate and Transport Processes in Aquatic Systems
 - WA18
 - Impacts of Pollutant Discharges on Aquatic Systems
 - WA20
- Environmental Socio-Economic Research: Environmental Damages and Benefits
 - SE01

AIR QUALITY RESEARCH: ATMOSPHERIC PROCESSES (including
Source-Receptor Links)

ISSUE: AR02

Physical and chemical processes involved in atmospheric transport of toxics, and acid rain.

Type of Research Needed:*

- Modelling and field studies of dispersion from non-standard sources (e.g. mine tailings, fugitive emissions).
 - Modelling of concentration fluctuations; e.g. odours.
 - Study of the quantification of boundary layer turbulence and development of meteorological instruments for its characterization.
 - Study of building wake dispersion.
 - Study of atmospheric deposition and transformation of substances involved in the acid rain problem and other pollutant studies.
 - Refinement of long-range and mesoscale atmospheric transport modelling including physical modelling of stable atmospheric dispersion and heavy gas dispersion in a complex urban setting.
 - Determination of the transportation and deposition mechanisms of airborne persistent toxic compounds.
 - Cumulus cloud parameterization in long-range transport models.
 - Studies of atmospheric chemistry related to global climate problems and ozone depletion.
-

*See Also:

Water Quality Research:	Managing Non-Point Sources of Pollution - WA10
Liquid and Solid Waste Research:	Contaminant Fate and Transport Systems in Aquatic Systems - WA19
Analytical Method Development:	Waste Handling - LS03
Environmental Socio-Economic Research:	Air and Water Analysis - AN15
	Cost of Controls and Mitigation - SE02
	Enviro-Economic Modelling - SE06

AIR QUALITY RESEARCH: ATMOSPHERIC PROCESSES (including
Source-Receptor Links)

ISSUE: AR03

Improved emergency response capability.

Type of Research Needed:*

- Improvement of the methods for calculating toxic compound concentrations downwind of emergency sites.

*See Also:

Air Quality Research:

Instrument Development and Application
- AR06

AIR QUALITY RESEARCH: SOURCES/INVENTORIES

ISSUE: AR04

Industrial/commercial emissions.

Type of Research Needed:*

- Development of new techniques for identification and quantification of emissions of PCDF, PCCD, PAH, PCB, pesticides, and trace metals, etc. from various area and point sources.
- Development of inexpensive stack samplers and sampling techniques which can be quickly put in place e.g. reliable opacity monitors.
- Development of simple, rugged field analytical methods for landfill air contaminant emissions.

***See Also:**

Liquid and Solid Waste Research:	Waste Handling - LS03
Analytical Method Development:	Air Analysis - AN16
Environmental Socio-Economic Research:	Cost of Controls and Mitigation - SE02

AIR QUALITY RESEARCH: SOURCES/INVENTORIES

ISSUE: AR05

Stationary domestic sources and mobile sources.

Type of Research Needed:*

- Determination of the quality and significance of residential burning of solid fuels on air and precipitation quality.
- Chemical characterization of the exhaust of internal combustion engines with special reference to individual organic compounds and trace metals, and quantification of emission rates.

See also:

Environmental Socio-
Economic Research:

Cost of Controls and Mitigation
- SE02

AIR QUALITY RESEARCH: INSTRUMENT DEVELOPMENT AND APPLICATION

ISSUE: AR06

Monitoring capability for air pollutants.

Type of Research Needed:*

- Development of monitoring techniques for toxic substances, (particularly target compounds for Regulation 308).
- Development of sampling methods for semi-volatile toxics e.g. PAH, PCDD, pesticides, etc.
- Study of high resolution and multidimensional (high resolution) GC and development of a data base for mobile monitoring of organic compounds.
- Determination of the monitoring capabilities required to adequately assess human exposure to air pollutants.
- Development of measurement methods for arsenic and other volatile metals and organometallics.
- Study of the ion chemistry of CI/MS and CI/MS/MS and development of the data base for organic compounds specific to APCI source (required for application to TAGAs).
- Development of portable reliable field monitors and samplers for specific contaminants for emergency response applications.
- Development and evaluation of air and deposition monitoring equipment suitable for routine monitoring in remote areas of Ontario.

*See Also:

Water Quality Research:
Liquid and Solid Waste
Research:
Analytical Method
Development:

Wastewater Treatment - WA04, WA07
Waste Handling - LS03
Landfill Technology - LS11
Air Analysis - AN16

AIR QUALITY RESEARCH: CONTROL AND REMEDIAL TECHNOLOGY

ISSUE: AR07

New control technology, devices and processes.

Type of Research Needed:*

- Development of accurate, unbiased assessment techniques for new control technologies for atmospheric contaminants of major concern in Ontario.
- Development of new control processes to control air emissions.

*See Also:

Environmental Socio-Economic Research:

Cost of Controls and Mitigation
- SE02

Environmental Protection Industry
- SE04

WATER QUALITY RESEARCH NEEDS

WATER QUALITY RESEARCH

Research needs related to water and the aquatic environment continue to cover a broad range of concerns and issues. The following needs that are identified reflect the Ministry's interests in establishing improved treatment processes for the Province's drinking water supplies and the removal or neutralization of source wastes, developing a better understanding of the cause-effect relationships in aquatic systems so that efforts can be directed to deal more effectively with water quality impacts, and determining improved environmental evaluation techniques.

Water research requirements have been grouped into the following six categories, involving 28 issues and about 125 specific needs:

- 1) Wastewater Treatment
- 2) Managing Non-Point Sources of Pollution
- 3) Contaminant Fate and Transport Processes in Aquatic Systems
- 4) Impacts of Pollutant Discharges on Aquatic Systems
- 5) Drinking Water
- 6) Effects of Acidic Deposition and Long Range Transport of Contaminants.

Once again, the Ministry's high priority in water research relates to evaluations of the significance of hazardous contaminants and minimization of these contaminants as a threat to our natural waters and drinking water supplies. This emphasis is reflected by the vast majority of the 28 research issues and related needs that have been identified. Studies carried out by universities and private sector consultants within the Ministry's environmental research program provide a substantial information base that contributes to the formulation of effective legislation, policies and workable solutions for resolving the numerous problems and concerns presented by hazardous contaminants in our aquatic ecosystem.

WATER QUALITY RESEARCH
Issues of Immediate Concern

ISSUE:

- WA05 Fate and Removability of Hazardous Compounds in Municipal Water Pollution and Control Plants
- WA06 Innovative Sewage Treatment Process Research
- WA07 Compliance and Monitoring Techniques
- WA13 Remedial Measures to Minimize Pollution Impact
- WA14 Spatial Analysis of Water Quality
- WA15 Effects of Timber Management Practices on Water Quality
- WA19 Fate and Pathways of In-Stream Pollutants Associated With Suspended Sediments
- WA20 Assessing Impacts of Point Source Discharges
- WA22 Impacts of In-Place Pollutants in Sediments in the Aquatic Ecosystem
- WA24 Drinking Water Quality Objectives and Treatment Processes
- WA25 Nitrate Contamination of Aquifers in Relation to Future Development of Individual and/or Communal Groundwater Supplies
- WA27 Distribution Behaviour and Effects of Low Level Trace Metals in Aquatic Systems

SUMMARY OF WATER QUALITY RESEARCH ISSUES

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
<u>WATER QUALITY RESEARCH</u>			
Wastewater Treatment	WA01 Efficiencies of selected conventional and advanced wastewater treatment systems currently used in the Ontario pulp and paper, steel and petroleum/petrochemical industry.	20	AN11/83 AN17/89 SE02/100
	WA02 Efficiencies of selected conventional and advanced wastewater treatment systems used by industrial concerns discharging wastes to municipal sewer systems.	21	AN11/83 SE02/100
	WA03 Volatile chemicals in sewer system and their treatment.	22	SE02/100
	WA04 Emerging technologies for industrial process changes to reduce contaminant loadings to waste streams.	23	AR06/13 LS02/54 SE02/100 SE03/101
	WA05 Fate and removability of hazardous compounds in municipal water pollution control plants.	24	AN11/83
	WA06 Innovative sewage treatment process research.	25	AR07/14 SE02/100
	WA07 Compliance and monitoring techniques.	26	AR06/13 AN07/79 SE03/101
Managing Non-Point Sources of Pollution	WA08 Natural occurrence of some organic and inorganic contaminants in surface and groundwaters.	27	AN15/87
	WA09 Impacts of agricultural tile drainage on receiving watercourses.	28	

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Managing Non-Point Sources of Pollution (continued)	WA10 Effects of intensive crop production practises on groundwater quality. WA11 Pesticide/herbicide residues in tributaries. WA12 Uncertainty in nutrient/contaminant loadings and the projected impact on the Great Lakes. WA13 Remedial measures to minimize pollution impact. WA14 Spatial analysis of water quality. WA15 Effects of timber management practices on water quality. WA16 Contaminants in combined sewage overflows (CSO) and stormwater runoffs (SWR) and development of optimal control options.	29 30 31 32 33 34 35	SE02/100 SE03/101 SE02/100
Contaminant Fate and Transport Processes in Aquatic Systems	WA17 Persistence, migration and breakdown processes of selected hazardous contaminants in soil and groundwater. WA18 Modelling contaminant fate and transport in aquatic systems. WA19 Fate and pathways of in-stream pollutants associated with suspended sediments.	36 37 38	AR01/8 LS13/65 AN15/87

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Impacts of Pollutant Discharges on Aquatic Systems	WA20 Assessing impacts of point source discharges. WA21 Information gaps in developing water quality criteria. WA22 Impacts of in-place pollutants in sediments on the aquatic ecosystem.	39 41 42	AR02/9 AN11/83 AN17/89 SE01/98 SE06/104 AN17/89 SE01/98 SE02/100
Drinking Water	WA23 Removal capabilities of treatment techniques for specific trace contaminants in drinking water. WA24 Drinking water quality objectives and treatment processes. WA25 Nitrate contamination of aquifers in relation to future development of individual and/or communal groundwater supplies.	43 44 45	SE03/101
Effects of Acidic Deposition and the Long Range Transport of Contaminants	WA26 Effects of acidification on biota. WA27 Distribution, behaviour and effects of low level trace metals in aquatic systems. WA28 Effects of organic contaminants associated with long range transport.	46 47 48	AR01/8 SE06/104 AR01/8 AR02/9 AR01/8

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WAO1

Efficiencies of selected conventional and advanced wastewater treatment systems currently used in the Ontario pulp and paper, steel and petroleum/petrochemical industry.

Type of Research Needed:*

- Establishment and testing of the usefulness of surrogate chemical parameters for monitoring chlorinated organics in pulp and paper mill effluents.
- Development and assessment of Best Management Practices.
- Evaluation of toxicity to fish and other aquatic organisms and taste and odour/tainting potential of influent and effluent streams and identification of probable associations/correlations of these effects with the contaminants (and their levels) found.
- Comparison of removal efficiencies of different systems and identification of the major design and operating factors influencing removal.

***See Also:**

Analytical Method
Development:

Environmental Socio-Economic
Research:

Drinking, Surface, Wastewater
Analysis -AN11

Biological Analysis - AN17

Cost of Controls and Mitigation
- SE02

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA02

Efficiencies of selected conventional and advanced wastewater treatment systems used by industrial concerns discharging wastes to municipal sewer systems.

Type of Research Needed:*

- Comparison of removal efficiencies of different systems and identification of major design and operating factors influencing removal for the following sectors:
 - organic chemicals sector
 - printing and publishing sector
 - electrical and mechanical equipment sector
 - waste recycling sector (including solvent, drum, oil, battery and metal recyclers)
 - food and kindred products sector
 - manufacturing sector
 - services sector.
- Development and assessment of Best Management Practices.

***See Also:**

Analytical Method Development: Drinking, Surface, Wastewater Analysis - AN11

Environmental Socio-Economic Research: Cost of Controls and Mitigation - SE02

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA03

Volatile chemicals in sewer systems and their treatment.

Type of Research Needed:*

- Study of the fate and transport of volatile organic compounds in sewer systems.
- Study of the fate and transport of odour compounds in sewer systems.
- Development and assessment of technology for the control of volatile organics and odour compounds in sewer systems, pumping stations and the headworks of STP.

*See Also:

Environmental Socio-Economic
Research:

Costs of Controls and Mitigation
-SE02

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA04

Emerging technologies for industrial process changes to reduce contaminant loading to waste streams.

Type of Research Needed:*

- Assessment of industrial processes to reduce toxic loadings to wastewater streams (eg. replacement of chlorine with oxygen delignification in pulp bleacheries).
- Evaluation of methods of spill control and of inplant treatment to reduce contaminant loading to waste streams.
- Evaluation of ultraviolet light and oxidizers (such as H₂O₂) to reduce contaminant loads in selective organic streams.
- Evaluation of applicability of electrolysis for metal removal from wastewater streams.

***See Also:**

Air Quality Research:

Instrument Development and Application - AR06

Liquid and Solid Waste Research:

Waste Handling - LS02

Environmental Socio-Economic Research:

Costs of Controls and Mitigation - SE02

Evaluation Tools and Applications - SE03

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA05

Fate and removability of hazardous compounds in municipal water pollution control plants.

Type of Research Needed:*

- Identification and use of surrogate compounds to determine fate and treatability of other compounds.
- Assessment of the fate, removability and stability of hazardous contaminants during and after sludge treatment.
- Grouping of hazardous substances using Quantitative Structure Activity Relationships (QSAR) or other techniques to categorize and reduce priority pollutant lists.
- Development of a method to predict the biodegradability of trace organic contaminants in municipal wastewater treatment systems.

*See Also:

Analytical Method Development: Drinking, Surface, Wastewater Analysis - AN11

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA06

Innovative sewage treatment processes.

Type of Research Needed:*

- Assessment of the sequencing batch reactor, biological phosphorus removal and integrated sewage treatment and energy production plants.
- Assessment of bio-augmentation and bio-stimulation processes to improve the removal of organic contaminants by municipal STP, and their ability to withstand organic shock loads.
- Assessment of mixed biological/activated carbon process to improve hazardous contaminants removal.
- Development of technology which incorporates municipal wastewater and associated nutrients into agricultural processes.

***See Also:**

Air Quality Research:

Control and Remedial Technology

- AR07

Environmental Socio-Economic
Research:

Costs of Controls and Mitigation

- SE02

WATER QUALITY RESEARCH: WASTEWATER TREATMENT

ISSUE: WA07

Compliance and monitoring techniques.

Type of Research Needed:*

- Development of innovative techniques and mechanisms to effectively monitor, identify (in field) and determine the source of a hazardous contaminant discharge from industrial, commercial or institutional premises.
- Assessment of on-site effluent toxicity measurement procedures with respect to reliability, efficiency, ease of use and cost.
- Development of statistically valid sampling strategies to assist in the assessment of chemicals of concern from the MISA Effluent Monitoring Priority Pollutant List.
- Development of procedures for the rapid screening of MISA Effluent Monitoring Priority Pollutant List substances in effluents measured in MISA to identify problematic compounds.

*See Also:

Air Quality Research:

Instrument Development and Application - AR06

Analytical Method Development:

Drinking, Surface, Wastewater Analysis - AN07

Environmental Socio-Economic Research:

Evaluation Tools and Applications - SE03

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA08

Natural occurrence of some organic and inorganic contaminants in surface and ground waters.

Type of Research Needed:*

- Determination of sources, availability and significance of trace metals, fluoride, aromatics, radon from specific geological formations, (e.g. limestone, igneous rocks, oil-bearing shales).
- Evaluation of the significance of substances (eg. phenols) produced by the decay of vegetation on water quality and aquatic life (tainting, toxicity).
- Development of concepts of ecoregion, surface water classification schemes and attainable water quality.

*See Also:

Analytical Method Development: Air and Water Analysis - AN15

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA09

Impacts of agricultural tile drainage on receiving watercourses.

Type of Research Needed:

- Evaluation of nutrients and solids transport under varying cropping and tillage conditions.
- Evaluation of tile drainage systems on erosion and downstream siltation.
- Evaluation of alternatives to tile drainage systems.

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA10

Effects of intensive crop production practices on groundwater quality.

Type of Research Needed:*

- Investigation of the relationship between cropping and fertilization practices and groundwater quality.

*See Also:

Environmental Socio-Economic
Research:

Costs of Controls and Mitigation
- SE02

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA11

Pesticide/herbicide residues in tributaries.

Type of Research Needed:*

- Assessment of frequency and trends in detections of pesticides/herbicides in water, sediment and biota of selected tributaries (Grand/Saugeen/Thames).
- Development of a screening model to evaluate likely management scenarios.
- Determination of the aquatic environmental impact of pesticide/herbicide residues in tributaries.

*See Also:

Environmental Socio-Economic
Research:

Evaluation Tools and Applications
- SE03

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA12

Uncertainty in nutrient/contaminant loadings and the projected impact on the Great Lakes.

Type of Research Needed:

- Stochastic analysis of ambient water quality data.
- Assessment of impact of uncertainty in long-term phosphorus loadings to Great Lakes phosphorus mass balances.
- Development of methods to better quantify low level contaminant loadings.
- Assessment of reliability and trends in nutrient/contaminant loadings in Ontario tributaries.

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA13

Remedial measures to minimize pollution impacts.

Type of Research Needed:*

- Development of reliable domestic and dairy waste treatment systems which function well in poorly drained soils.
- Documentation of the impact of vegetative buffer strips adjacent to streams and municipal drains on water quality.
- Development of remedial processes to minimize erosion and subsequent downstream siltation.
- Evaluation of efficacy of vegetative buffer strips at reducing nutrient inputs from lakeshore development on Canadian Shield lakes.
- Evaluation of the impacts of small-scale lakefilling on water quality and resident aquatic communities including effects of physical factors (e.g. silt), chemical factors, and contaminants in fill.
- Investigation of criteria for the design, application maintenance and retro-fit of urban channels with more "natural" channel designs.

*See Also:

Environmental Socio-Economic
Research:

Costs of Controls and Mitigation
- SE02

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA14

Spatial analysis of water quality.

Type of Research Needed:*

- Development of statistical and mathematical water quality models for integration and analysis of spatial data bases within the context of Geographic Information Systems (GIS).
- Overlay and analysis of MOE water quality data bases (e.g. surface waters, groundwater, point source discharges, etc.), with related data bases, (e.g. geology, soils, ecosystem land use, agricultural chemical usage, population, epidemiology, socioeconomic indicators, etc.), to ascertain statistical interrelationships on appropriate spatial scales.
- Development of spatial models for water quality management and policy development.

***See Also:**

Environmental Socio-Economic Research:

Environmental Damages and Benefits - SE01
Evaluation Tools and Applications - SE03
Enviro-Economic Modelling - SE06

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA15

Effects of timber management practices on water quality.

Type of Research Needed:

- Evaluation of effects of access road construction on water quality (especially suspended solids and nutrients) and biota of streams and lakes in Ontario boreal forests.
- Evaluation of various timber harvest practices on water quality and biota of streams and lakes in Ontario boreal forests.
- Investigation of new approaches for minimizing/mitigating the impact of timber harvesting practices on water quality and biota.

WATER QUALITY RESEARCH: MANAGING NON-POINT SOURCES OF POLLUTION

ISSUE: WA16

Contaminants in combined sewage overflows (CSO) and stormwater runoff (SWR) and development of optimal control options.

Type of Research Needed:

- Definition of the distribution of contaminants between settleable and non-settleable solids plus liquid phases in CSO and SWR.
- Investigation of the removability of selected contaminants in CSO and SWR by conventional means (e.g. solids removal and/or street sweeping).
- Development and evaluation of innovative techniques and mechanisms to remove or fix contaminants in surface water runoff from existing developed areas.
- Development and evaluation of reliable sampling equipment and methods for SWR and CSO treatment facility compliance monitoring. Parameters to be examined should include microbiological, suspended/total solids, nutrients and metals.
- Characterization and evaluation of SWR control pond and catchbasin sediments. Parameters to be examined should include microbiological, suspended/total solids, nutrients, metals and depth and level of contamination.
- Evaluation of various groundwater recharge techniques (i.e. stormwater filter beds, pond, pavements, trenches, ditches, swales, sewers and catchbasins) and other best management practices to reduce pollutant loads for SWR. This evaluation should include potential of groundwater contamination (i.e. metals, nitrates, bacteria, petroleum products), loading reductions to receivers, benefits to aquifer improvements, cost comparison to conventional practices, operation and maintenance concerns and design life expectancies.
- Evaluation of on-line quantity/quality SWR control ponds with regards to aquatic life and habitat.

WATER QUALITY RESEARCH: CONTAMINANT FATE AND TRANSPORT
PROCESSES IN AQUATIC SYSTEMS

ISSUE: WA17

Persistence, migration and breakdown processes of selected contaminants in soil and groundwater.

Type of Research Needed:*

- Laboratory and field tests of half-life and migration of hazardous contaminants in the various soil sediments and groundwater conditions found in Ontario.
- Determination of the alteration in mobility of a given hydrophobic contaminant or a mixture of substances due to the presence of solvents.

***See Also:**

Air Quality Research:	Contaminant Effects/Toxicity/- Fates - AR01
Liquid and Solid Waste Research:	Groundwater Contamination - LS13
Analytical Method Development:	Air and Water Analysis - AN15

WATER QUALITY RESEARCH: CONTAMINANT FATE AND TRANSPORT
 PROCESSES IN AQUATIC SYSTEMS

ISSUE: WA18

Modelling contaminant fate and transport in aquatic systems.

Type of Research Needed:

- Prediction of currents from wind data at Great Lake nearshore locations where no current meters have been operated.
- Development of a numerical model to predict the extent and water quality of a river plume where it merges into a lake.
- Development of a numerical model to predict the hydrodynamics of the whole lake and then focus on a local area for better resolution.
- Development of predictive models to identify depositional areas and areas of resuspension and transport in streams and the nearshore zone of the Great Lakes.
- Measurement and modelling of sediment resuspension and redistribution due to wave action, storms and currents.

WATER QUALITY RESEARCH:

CONTAMINANT FATE AND TRANSPORT
PROCESSES IN AQUATIC SYSTEMS

ISSUE: WA19

Fate and pathways of in-stream pollutants associated with suspended sediments.

Type of Research Needed:

- Investigation of the relationships between metal levels in suspended sediment, their geochemical distribution and factors that influence them (pH, hardness).
- Investigation of the contribution of sediment entrainment in rivers to bacterial levels.
- Investigation of the relationship between suspended sediments and organic contaminant levels.
- Investigation of sediment dynamics and retention times with a focus on the Great Lake connecting channels.
- Evaluation of potential bioavailability of contaminants associated with suspended sediments under a range of physical and chemical water quality conditions.

*See Also:

Multimedia Contaminants
and Biotechnology Research:

Risk Identification and
Assessment Methods - MM03

WATER QUALITY RESEARCH: IMPACTS OF POLLUTANT DISCHARGES ON AQUATIC SYSTEMS

ISSUE: WA20

Assessing impacts of point source discharges.

Type of Research Needed: *

- Development of routine procedures for measurement of biochemical and physiological stress in organisms exposed to contaminants.
 - Development of mutagenic and carcinogenic test systems related to aquatic organisms.
 - Evaluation of the significance of elevated levels of heavy metals and organic compounds on the growth and reproductive success of aquatic organisms.
 - Assessment of the importance of modifying factors (hardness, pH, temperature) on the toxicity and bioavailability of metals and other substances.
 - Significance (short and long term) of recent increases in nitrogen levels in Great Lakes and tributary waters.
 - Evaluation of responses to decreasing phosphorus levels in the Great Lakes system.
 - Development of surrogates for rapid and effective monitoring of hazardous waste discharges.
 - Evaluation of the effects of bioaccumulated organics and metals on the health of aquatic organisms at various levels in the food chain, leading to development of guidelines for biological organisms.
 - Evaluation of the impact of contaminants on community structure.
 - Identification of factors affecting metal and chlorinated organics accumulation in filamentous algae in lakes and the significance and fates of metals subject to bioaccumulation.
 - Determination of the usefulness of the concept of "size classification" on pelagic and benthic food chain models.

/continued

WATER QUALITY RESEARCH: IMPACTS' OF POLLUTANT DISCHARGES ON
 AQUATIC SYSTEMS

ISSUE: WA20 (continued)

Assessing impacts of point source discharges.

Type of Research Needed:*

- Development of procedures for modelling the toxic effects of mixtures of chemicals found in effluents.
- Determination of the application of biotic indices (e.g. Hilsinhoff's index of biotic integrity) to benthic communities of the Great Lakes.
- Determination of model parameters and coefficients (such as uptake/depuration rate) necessary to operate existing simulation models e.g. WASTOX).
- Development of valid sampling design and statistical evaluation for identifying non-compliance with Provincial Water Quality Objectives in areas of impact.
- Development of procedures for optimizing sampling frequency for determining contaminant loadings for point source discharges and total contaminant loads to lake basins (e.g. Lake Ontario).
- Identification of tainting compounds discharged in pulp and paper effluents.
- Determination of the relationship between total chlorinated organic compounds (AOX) and receiving water impacts.

*See Also:

- | | |
|---|--|
| Air Quality Research: | Contaminant Effects/Toxicity/-
Fate - AR02 |
| Analytical Method Development: | Drinking, Surface, Wastewater
Analysis - AN11 |
| Environmental Socio-Economic
Research: | Biological Analysis - AN17 |
| | Environmental Damages and Benefits
- SE01 |
| | Enviro-Economic Modelling
- SE06 |

WATER QUALITY RESEARCH: IMPACTS OF POLLUTANT DISCHARGES ON AQUATIC SYSTEMS

ISSUE: WA21

Information gaps in developing water quality criteria.

Type of Research Needed: *

- Information from acute and chronic toxicity studies on fish and invertebrates needed to allow development of Provincial Water Quality Objectives (specific chemicals and tests needed available on request from Research Co-ordinator).

WATER QUALITY RESEARCH:

IMPACTS OF POLLUTANT DISCHARGES ON AQUATIC SYSTEMS

ISSUE: WA22

Impacts of in-place pollutants in sediments on the aquatic ecosystem.

Type of Research Needed: *

- Measurements of uptake and release of trace substances from sediments.
 - Assessment of transformations of trace organics and inorganics in sediments.
 - Determination of availability of trace organics and heavy metals in sediments and suspended sediments to biota.
 - Development of techniques for immobilizing contaminants in sediment such as chemical fixation, overlaying with clean sediment.
 - Assessment of effectiveness of alternate approaches to isolating, removing, treating and/or disposing of contaminated sediments.
 - Development of simple, reliable, laboratory based techniques to evaluate the potential impacts of in-place pollutants on the aquatic ecosystem.
 - Determination of significance of suspended solids on fish health (gill clogging, feeding behaviour etc.).

See Also:

Analytical Method Development: Biological Analysis - AN17
Environmental Socio-Economic Environmental Damages and Benefits
Research: - SE01
Costs of Controls and Mitigation
- SE02

WATER QUALITY RESEARCH: DRINKING WATER

ISSUE: WA23

Removal capabilities of treatment techniques for specific trace contaminants in drinking water.

Type of Research Needed:*

- Evaluation of the effectiveness of innovative treatment techniques (such as resin adsorption, reverse osmosis, aeration, biological filtration, GAC, PAC, ozonation and treatment train modifications) for hazardous contaminant removal.
- Development of protocols for the assessment of treatment methodologies for groups of compounds and specific trace contaminants.
- Development of a computer assisted treatment process choice for use as a decision making framework for the removal/reduction of trace contaminants from drinking water.
- Determination of the resistance of specific pathogens to disinfection practices in drinking water treatment plants.

*See Also:

Environmental Socio-Economic
Research:

Evaluation Tools and Applications
- SE03

WATER QUALITY RESEARCH: DRINKING WATER

ISSUE: WA24

Drinking water quality objectives and treatment processes.

Type of Research Needed:

- Provision of information required for the development of drinking water quality objectives for MOE list of priority chemicals.
- Assessment of use of mutagenicity testing in assessing drinking water treatment processes.
- Development of a means of predicting/establishing short-term variations in water quality at intakes and establishing subsequent treatment technology.
- Investigation of the by-products of the use of alternative treatment processes.
- Investigation of the production of additional contaminants in finished water because of the application of chlorine to water containing traces of contaminants (e.g. trichlorotoluene from water containing toluene).

WATER QUALITY RESEARCH: DRINKING WATER

ISSUE: WA25

Nitrate contamination of aquifers in relation to future development of individual and/or communal groundwater supplies.

Type of Research Needed:

- Study of the total nitrate loading on aquifers from septic system effluents, fertilizers and other potential sources.
- Study of the magnitude of seasonal nitrate level fluctuations in different aquifers (shallow end intermediate).
- Development of protocol to estimate total nitrate loading expected from proposed and existing development.
- Assessment of the need and feasibility of nitrate removal systems in communal systems and/or small private systems.
- Investigation of the use of nitrate as an indicator parameter for other potential contaminants, especially organics originating from septic effluents.

WATER QUALITY RESEARCH: EFFECTS OF ACIDIC DEPOSITION AND THE LONG RANGE TRANSPORT OF CONTAMINANTS

ISSUE: WA26

Effects of acidification on biota.

Type of Research Needed:*

- Determination of the current extent of acidification impacts on sensitive biota.
- Determination of the extent and mechanisms responsible for the occurrence of spring mortality in populations of biota in soft water lakes.
- Determination of the effects of surface water acidification on biota in running water and a definition of mechanisms of population loss.
- Assessment of the relationship between acidity and phosphorus utilization in acidic lakes, including phosphatase activity, herbivore effects and light, pH and inorganic carbon requirements.

***See Also:**

Air Quality Research:

Contaminant Effects/Toxicology/-

Fate - AR01

Environmental Socio-Economic
Research:

Enviro-Economic Modelling

- SE06

WATER QUALITY RESEARCH: EFFECTS OF ACIDIC DEPOSITION AND THE
 LONG RANGE TRANSPORT OF ORGANICS

ISSUE: WA27

Distribution, behaviour and effects of low level trace metals in aquatic systems.

Type of Research Needed:*

- Assessment of mercury methylation/demethylation rates in oligotrophic softwater lakes and their watersheds.
- Development of empirical models to describe the partitioning of mercury and methyl mercury in watershed soils, streams and oligotrophic softwater lakes.
- Development of mathematical models of methyl mercury accumulation by aquatic biota to clarify the influence of acidification and the factors affecting uptake and elimination.
- Determination of the microorganisms responsible for mercury methylation/demethylation and the effect of acidification on these organisms.
- Determination of fate and transport of trace metals associated with atmospheric deposition in watershed soils, streams and softwater lakes.
- Evaluation of the uptake and chronic effects of trace metal levels (Pb, Cd, Cu, Zn) on aquatic biota.
- Determination of metal enrichment in waterfowl and their prey.
- Determination of the mechanisms of metal enrichment of the food chain of acidified lakes.

***See Also:**

Air Quality Research:

Contaminant Effects/Toxicology/-
Fates - AR01, - AR02

Environmental Socio-Economic
Research:

Environmental Damages and
Benefits - SE01

Enviro-Economic Modelling - SE06

WATER QUALITY RESEARCH: EFFECTS OF ACIDIC DEPOSITION AND THE
LONG RANGE TRANSPORT OF CONTAMINANTS

ISSUE: WA28

Effects of organic contaminants associated with long range transport.

Type of Research Needed: *

- Determination of extent and significance of bioaccumulation of organic contaminants associated with long range transport.
- Determination of the fate of organic contaminants associated with long range transport and the pathways of transport from the atmosphere through the terrestrial system and into the aquatic system.

***See Also:**

Air Quality Research:

Contaminant Effects/Toxicology/-
Fates - AR01

Multimedia Contaminants and
Biotechnology Research:

Risk Identification and Assessment
Methods - MM03

LIQUID AND SOLID WASTE RESEARCH NEEDS

LIQUID AND SOLID WASTE RESEARCH

Research needs in the handling, treatment and disposal of liquid and solid wastes, not conveyed to municipal sewage treatment plants, are as diverse as the materials that make up the waste streams.

Future research needs, identified by the Ministry of the Environment, fall into one or more of three broad categories:

- Waste Handling
- Waste Reduction
- Landfill Technology

A total of thirteen general issues have been identified within these categories.

Our primary thrust is to reduce the amount of waste that must be treated or landfilled. Accordingly, there is a need for research into the "3R's" of waste management; the reduction, recycling, and reuse of waste materials.

For those waste materials not encompassed by the 3R's program, characteristics should be determined so that the need for treatment and the required degree of treatment can be accurately identified. Having identified a need for some type of degree of treatment, it becomes necessary to develop and demonstrate the appropriate treatment methodologies.

Landfill sites will continue to be the ultimate repository of residual wastes, treated or untreated, and therefore it is a necessary requirement to investigate, improve and enhance landfill technology to ensure safe and aesthetically acceptable disposal of these wastes. This has been a major field of study in the past and continues to deserve attention. In particular, the control of contaminant migration from landfill sites and the safe containment of potentially dangerous wastes, including biomedical wastes and incinerator ash requires study as does site rehabilitation and remediation for existing sites.

LIQUID AND SOLID WASTE RESEARCH

Issues of Immediate Concern

ISSUE:

- LS02 Methods and Materials for the Treatment of
 Wastes and Waste By-Products
- LS05 Ways and Means of Reducing the Volumes and
 Contaminated Mass of Waste Streams
- LS06 Ways and Means of Reusing and Recycling
 Materials Currently in the Waste Stream
- LS10 Characteristics and Impacts of Landfill
 Leachate
- LS13 Groundwater Contamination from Landfills

SUMMARY OF LIQUID AND SOLID WASTE RESEARCH ISSUES

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
<u>LIQUID AND SOLID WASTE</u>			
Waste Handling	LS01 Characteristics of waste materials and the behaviour of wastes under various and varying conditions. LS02 Methods and materials for the treatment of wastes and waste by-products. LS03 Methods and materials for the thermal destruction of wastes and waste by-products. LS04 Management of chlorofluoro-carbons.	53 54 55 56	AN01/73 AR07/14 WA04/23 SE02/100 AR04/11 AR06/13 AR07/14 AN14/86 AN16/88 SE02/100
Waste Reduction	LS05 Ways and means of reducing the volumes and contaminated mass of waste streams. LS06 Ways and means of reusing and recycling materials currently in the waste stream.	57 58	SE02/100 SE03/101 SE02/100 SE03/101
Landfill Technology	LS07 Wastes degradation and decomposition in landfills. LS08 Methods, materials and performance of landfill covers.	59 60	AN14/86 SE02/100

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Landfill Technology (continued)	<p>LS09 Methods, materials and performance of landfill liners.</p> <p>LS10 Characteristics and impacts of landfill leachate.</p> <p>LS11 Production, control, collection and use of landfill gas.</p> <p>LS12 End-use of closed landfills.</p> <p>LS13 Groundwater contamination from landfills.</p>	61 62 63 64 65	AN14/86 AR06/13 SE01/98 WA17/36 AN13/85 AN15/87

LIQUID AND SOLID WASTE RESEARCH: WASTE HANDLING

ISSUE: LS01

Characteristics of waste materials and the behaviour of wastes under various and varying conditions.

Type of Research Needed:*

- Determination of "inert" wastes.
- Determination of the long term effects of wastes.
- Studies on toxic hazardous waste materials including:
 - Assessment of existing hazardous waste schedules,
 - development of criteria for listing of hazardous waste based on toxicological studies (chronic and acute toxicity, persistence, bioaccumulation, leachability, etc.).

Development of test criteria to define waste characteristics.

*See Also:

Analytical Method Development: Refinement of Analytical Techniques - AN01

LIQUID AND SOLID WASTE RESEARCH: WASTE HANDLING

ISSUE: LS02

Methods and materials for the treatment and disposal of wastes and waste by-products.

Type of Research Needed:*

- Investigation of biological, chemical and physical treatment processes for solid and liquid wastes.
- Investigation of methods for solidification and/or encapsulation.
- Investigation of disposal methods for treatment process effluents.
- Methods for the design, collection, treatment, disposal, decontamination or reuse of pesticide containers.
- Development of non-thermal destruction technologies for municipal, industrial and biomedical wastes.

*See Also:

Air Quality Research:	Control and Remedial Technology - AR07
Water Quality Research:	Wastewater Treatment - WA04
Environmental Socio-Economic Research:	Costs of Controls and Mitigation - SE02

LIQUID AND SOLID WASTE RESEARCH: WASTE HANDLING

ISSUE: LS03

Methods and materials for the thermal destruction of wastes and waste by-products.

Type of Research Needed:*

- Investigation of high temperature destruction of municipal and industrial wastes including:
 - . improvements to state-of-the-art technology;
 - . field and laboratory studies;
 - . development of new technology for destruction and disposal of municipal and industrial wastes;
 - . characterization of treatment residue, its leachability and utilization or disposal;
 - . development of protocols for emission monitoring for hazardous contaminants.

*See Also:

Air Quality Research:	Source/Inventories - AR04 Instrument Development and Application - AR06 Control and Remedial Technology - AR07
Analytical Method Development:	Landfill, Leachate, Effluent, Hazardous Waste Analysis - AN14 Air Analysis - AN16
Environmental Socio-Economic Research:	Cost of Controls and Mitigation - SE02

LIQUID AND SOLID WASTE RESEARCH: WASTE HANDLING

ISSUE: LS04

Management of chlorofluorocarbons (CFC's)

Type of Research Needed:

- Development of destruction techniques for CFC's.
- Development of techniques for the recovery and disposal of CFC's.

*See Also:

Environmental Socio-Economic
Research:

Environmental Damages and
Benefits - SE01

LIQUID AND SOLID WASTE RESEARCH: WASTE REDUCTION

ISSUE: LS05

Ways and means of reducing the volumes and contaminated mass of waste streams.

Type of Research Needed:*

- Studies of waste reduction methodologies at the levels of:
 - . commercial
 - . industrial
 - . municipal
 - . post-consumer
- Investigation of improved manufacturing/processing/packaging practices, methods and materials for the purpose of waste reduction.

***See Also:**

Environmental Socio-Economic
Research:

Cost of Controls and Mitigation

- SE02

Evaluation Tools and Applications
- SE03

LIQUID AND SOLID WASTE RESEARCH: WASTE REDUCTION

ISSUE: LS06

Ways and means of reusing and recycling materials currently in the waste stream.

Type of Research Needed:*

- Development of sorting and treatment methods to improve purity.
- Study of processes for direct and indirect reuse and recycling of materials in the waste stream.
- Methods for reuse and recycling of automobile tires and household appliances.
- Development of composting technologies for household waste to improve quality and maximize uses of compost products.

*See Also:

- Environmental Socio-Economic Research: Cost of Controls and Mitigation
- SE02
Evaluation Tools and Applications
- SE03

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS07

Wastes degradation and decomposition in landfills.

Type of Research Needed:*

- Investigation of rates of degradation and decomposition.
- Investigation of rate and by-products of degradation of biodegradable plastics.

See Also:

Analytical Method Development:

Landfill, Leachate, Effluent,
Hazardous Waste Analysis
- AN14

Environmental Socio-Economic
Research:

Cost of Controls and Mitigation
- SE02

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS08

Methods, materials and performance of landfill covers.

Type of Research Needed:

- Development and evaluation of landfill cover designs in terms of:
 - materials
 - thickness
 - shape
 - infiltrative capacity
 - durability
 - rehabilitation and/or replacement

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS09

Methods, materials and performance of landfill liners.

Type of Research Needed:

- Development and evaluation of landfill liner designs in terms of:
 - materials
 - thickness
 - shape
 - leakage
 - durability
 - rehabilitation

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS10

Characteristics and impacts of landfill leachate.

Type of Research Needed:*

- Assessment of methods for collection, control and treatment of leachate.
- Determination of attenuation rates for leachate in groundwater.

*See Also:

Analytical Method Development: Landfill, Leachate, Effluent,
Environmental Socio-Economic Hazardous Waste Analysis - AN14
Research: Environmental Damages and
Benefits - SE01

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS11

Production, control, collection and use of landfill gas.

Type of Research Needed:*

- Development of a method to assess methane flux.
- Development of specific measurement methods for ventilation rates and flux.
- Development of methods to enhance gas production rate.

*See Also:

Air Quality Research:

Instrument Development and
Application - AR06

Environmental Socio-
Economic Research:

Environmental Damages and Benefits
- SE01

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS12

End-use of closed landfills.

Type of Research Needed:

- Development of closure techniques.
- Monitoring systems and materials for long term use.
- Study of legal and institutional impediments to future use.

LIQUID AND SOLID WASTE RESEARCH: LANDFILL TECHNOLOGY

ISSUE: LS13

Groundwater contamination from landfills.

Type of Research Needed:

- Investigations on the effects of leachates.
- Investigations on the effects of chemical spills.
- Development of methods for the improved detection and tracing of contaminant plumes.
- Development of methods for the improved prediction of plume development and movement.
- Development and demonstration of remediation methods and materials.
- Determination of "critical contaminant."

***See Also:**

Water Quality Research:

Contaminant Fate and Transport
Processes in Aquatic Systems
- WA17

Analytical Method Development: Landfill, Leachate, Effluent,
Hazardous Waste Analysis - AN13
Air and Water Analysis - AN15

ANALYTICAL METHOD DEVELOPMENT RESEARCH NEEDS

ANALYTICAL METHOD DEVELOPMENT RESEARCH

Virtually every aspect of environmental research requires sample analysis. Sound methodologies are required for studies of a wide range of organic and inorganic contaminants of drinking and surface waters, groundwater, landfill leachates, ambient air, stack emissions, hazardous wastes, sewage and pulp and paper sludges, and biological systems. In addition to developing new methods for performing qualitative and quantitative determinations at trace levels in complex matrices, there is a constant need to improve existing methods to allow for analysis of more samples, better and faster. Specific research needs cover the gamut of analysis steps from sampling to analyte identification, quantification, and data interpretation.

Research is needed in the analytical area to determine the effect of sampling protocols on analytical data, especially for microbiological parameters. Field methods for pre-concentration of viruses and integrative biological tests to identify problem areas in air, soil and water are required. Rugged field collection methods for large-volume aqueous samples are needed using sorbent cartridges or other means. Associated sample preservation, shipping and storage protocols to ensure analyte stability are equally important. Techniques for odorous compounds in water and air and non-open collection methods to avoid atmospheric contamination or degassing of groundwaters/landfill leachates are of special importance. A validated, tiered testing protocol for groundwater contaminants is also required, in addition to improved methods for semi-volatile organics and trace metals in ambient air. Canister sampling methods, plume dispersion models and improved prediction of precipitation events are all required to improve air and atmospheric deposition studies.

Samples often must be sub-aliquoted for analysis of multiple analytes and round-robin investigations. Effects of grinding, slicing, blending and other mixing and homogenization procedures on sample integrity need to be performed. Determination of analyte losses and the potential for artifact introduction and sample cross-contamination are especially important. Procedures to ensure the homogeneity of aqueous samples containing suspended particulates during sub-aliquoting also require investigation. Laboratory protocols for recovery and enumeration of pathogenic organisms need to be developed.

An ongoing need is to improve methods for the unambiguous identification of a broad range of organics in complex samples such as pulp and paper and sewage sludges. Methods to be investigated include advanced GC-MS techniques, FTIR, computer library matching, and other chemometrics techniques. Isolation and concentration methods to obtain large quantities of unidentified analytes are required to employ other spectroscopic techniques such as NMR. Improved chromatographic separation and HPLC fractionation techniques to simplify complex organic mixtures prior to mass spectrometry detection are also needed. Rapid

screening methods for trace metals in aqueous samples by using ICP-MS, GC-microwave plasma emission, or biological on-line monitoring are also of interest.

Microbiological identification enhancements are required for E. coli and group D. enterococci in water and sediments, as well as modification of such methods for the detection of other pathogens such as Salmonella and Campylobacteria. Similar methods to identify genotoxic compounds or conditions in the environment are needed. An ongoing problem is how to relate carcinogenicity and genotoxicity test responses to human health effects.

Improved quantification of target analytes is an ongoing research need. Development of novel GC detectors or improving the selectivity of conventional detectors is one approach to be considered. Development of improved cleanup techniques to isolate chemicals of concern also needs to be studied. The unambiguous determination of all 2,3,7,8-substituted dioxin/furan congeners is of special interest. To improve the quantitative analysis of selected target analytes in specific matrices, research is needed to develop validated analytical standards and SRMs.

For all of the preceding studies improvement of sample throughput and the analytical precision and accuracy are desired. Approaches include chemometric techniques for data analysis including development of expert systems for data analysis, QA/QC, and troubleshooting analytical instruments. Other enhancements can be obtained through the use of robotics and development of new sample preparation methods more suited to automation. One area of special interest is the extraction/concentration of samples using supercritical fluids.

In addition to all of the above, some critical Ministry programs have special requirements. Of particular importance are laboratory techniques to assess the leaching potential of specific wastes for hazardous waste classification. Methods for complex industrial effluents for the MISA program are also important. Specific research is required to evaluate interferences for the determination of inorganics in MISA effluents, to develop improved analyte detectability by matrix modification, and to improve and validate methods for quantifying volatiles associated with liquid and solid fractions of sludges. Special problems have been encountered with the complex samples derived from pulp and paper industries, for which research is needed for sediment and biota tissue analysis of resin and fatty acids and speciated phenols. In addition, methods for flowthrough field analysis of pulp and paper effluents to determine the impact of mill discharges are required. Research is also needed to develop methods for the source tracking of pollutants in air and water. Chemometric methods are needed to compare organic/inorganic analyte profiles to identify generic sample types, to identify specific sources of such groups of compounds as PCBs, dioxin/furans and toxaphene by studying their congener/isomer patterns, and by studying isotope ratios of elements such as lead.

ANALYTICAL METHOD DEVELOPMENT

Issues of Immediate Concern

ISSUE:

- AN01 Specificity and Identification Improvements to Trace Organic Compounds in Complex Matrices
- AN02 Automation of Analytical Methods
- AN03 Sample Integrity and Stability During Shipping, Storage and After Sub-Aliquoting/Homogenization
- AN05 Expert System Applications to Analytical Processes
- AN07 Broad Spectrum Scanning for Contaminants in Drinking, Surface and Wastewaters
- AN08 Analytical Method Development to Support MISA
- AN11 Sampling Protocols for Contaminants in Surface and Drinking Waters
- AN12 Analytical Method Development to Support Reg. 309
- AN14 Analytical Method Development to Assess Leaching Potential of Specific Wastes for Hazardous Waste Classification
- AN15 Isotope Ratios and Isomer Distribution Patterns Techniques Applied to Source Tracking of Pollutants
- AN16 Sampling and Analysis of Gaseous and Particulate Emissions in Air
- AN19 Development of Field Analytical Techniques for Environmental Contaminants

SUMMARY OF ANALYTICAL METHOD DEVELOPMENT

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
<u>ANALYTICAL METHOD DEVELOPMENT</u>			
Refinement of Analytical Techniques	AN01 Specificity and identification improvements to trace organic compounds in complex matrices.	73	LS01/53
	AN02 Automation of analytical methods.	74	
	AN03 Sample integrity and stability during shipping, storage and after sub-aliquoting/homogenization.	75	
	AN04 Validated analytical standards and standard reference materials.	76	
	AN05 Expert system applications to analytical processes.	77	
	AN06 Advanced data interpretation processes.	78	

SUMMARY OF ANALYTICAL METHOD DEVELOPMENT

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Drinking, Surface, Wastewater, Effluent Analysis	AN07 Broad spectrum scanning for contaminants in drinking, surface and wastewaters. AN8 Analytical method development to support MISA. AN9 Large volume sampling systems for preconcentration of low level toxic contaminants. AN10 Surrogate parameters for water monitoring. AN11 Sampling protocols for contaminants in surface and drinking waters. AN12 Analytical method development to support Reg. 309.	79 80 81 82 83 84	WA08/27 WA01/20 WA02/21 WA05/24

SUMMARY OF ANALYTICAL METHOD DEVELOPMENT

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Landfill, Leachate, Effluent, Hazardous Waste Analysis	AN13 Tiered testing of ground-water for landfill investigations.	85	LS13/65
	AN14 Analytical method development to assess leaching potential of specific wastes for hazardous waste classification.	86	LS03/55 LS10/62
Air and Water Analysis	AN15 Isotope ratios and isomer distribution patterns techniques as applied to source tracking of pollutants.	87	AR02/9 WA09/28 WA18/37 LS13/65
Air analysis	AN16 Sampling and analysis of gaseous and particulate emissions in air.	88	AR04/11 AR06/13 LS03/55
Biological Analysis	AN17 Biological and microbiological procedures.	89	AR07/14 WA01/20 WA22/42 WA23/43 WA24/44
	AN18 Genotoxicity testing.	90	
	AN19 Development of field analytical techniques for environmental contaminants.	91	

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF
ANALYTICAL TECHNIQUES

ISSUE: AN01

Specificity and identification improvements to the determination of trace organic contaminants in complex matrices.

Type of Research Needed:

- Improvement of selectivity for specific target analytes in gas chromatography by development of new columns with novel/mixed stationary phases.
- Development of new and improvement of existing techniques for the isolation of target compounds from complex matrices, e.g., GPC, HPLC, other chromatographic separations and wet chemical techniques.
- Improvements of GC-MS and other instrumental techniques for rapid broad-spectrum identification of organics in extremely complex matrices and for use when library search methods are inadequate.
- Development of rapid isomer-specific methods for the toxic 2,3,7,8-substituted congeners of chlorinated dibenzo-p-dioxins and dibenzofurans in complex mixtures containing both toxic and non-toxic congeners.
- Development of identification procedures using retention time and mass spectral data for GC-MS and of a retention index system either generically with n-alkanes or specifically with deuterated compounds of interest.
- Identification using specialized MS techniques such as positive and negative chemical ionization, exact mass determination, and MS-MS.
- Development of isolation and concentration techniques to obtain large quantities of unknown components to enable a wide variety of spectroscopic techniques to be used for compound identification.
- Development of mathematical and software fingerprinting techniques for rapid broad-spectrum identification.
- Improvements of existing separatory techniques for superior fractionation of complex sample matrices for instrumental analysis (e.g. GC-MS, FTIR, SFC-MS, SFC-FTIR-MS).

*See also:

Liquid & Solid Waste Research: Waste Handling
 - LS01

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF ANALYTICAL
TECHNIQUES

ISSUE: AN02

Automation of analytical methods.

Type of Research Needed:

- Development of software to improve reliability of automated identification of trace levels of analytes using a few characteristic ion masses by selected ion monitoring or a series of peak retention times and relative responses.
- Improvement of software for automated target compound quantitation using external or internal standardization and automated report generation for GC-MS.
- Development of customized software packages for GC-MS data interpretation for specific Ministry programs, including specialized data bases.
- Development of improved identification procedures for complex mixtures such as environmentally altered PCB, toxaphene, chloronaphthalenes.
- Application of robotics to sample preparation operations, especially where sample mixing is required.
- Development of new extraction/wet chemical techniques more readily adapted to automation.
- Development of automated cleanup procedures for chemical analysis.
- Investigation and refinement of supercritical fluid extraction and preparative chromatography techniques.
- Total automation of water samples requiring analysis by HPLC, GC or GC-MS.
- Total automation of solid sample analysis by SFE-GC or other techniques.
- Application of solid phase extraction technique in total automation of water samples requiring HPLC or GC analysis.

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF
ANALYTICAL TECHNIQUES

ISSUE: AN03

Sample integrity and stability during shipping, storage and after sub-aliquoting/homogenization.

Type of Research Needed:

- Determination of optimum conditions for shipping samples including time limitations, temperature effects, container design, addition of preservatives during sampling.
- Determination of sample integrity during storage including time limitations, temperature effects, addition of preservatives, especially for inorganics such as nutrients, and organics such as phenols, dioxins and PCB's.
- Comprehensive assessment of the stability with time of all inorganic and organic parameters routinely reported by MOE.
- Investigation of the effects of grinding, slicing, mixing, blending on homogeneity of sample and particle sizes.
- Investigation of analyte losses through sample homogenization steps or artifact introduction (i.e., trace metals using metal blender blades or organic carbon from homogenizer lubrication fluids).
- Investigation of the homogeneity of an aqueous sample in the presence of suspended particulates during sample sub-aliquoting and filtering.
- Investigation of problems related to splitting filters and polyurethane foam cartridges used for air sampling.
- Development of protocol for sub-aliquoting complex samples for round-robin samples.

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF
ANALYTICAL TECHNIQUES

ISSUE: AN04

Validated analytical standards and standard reference materials.

Type of Research Needed:

- Synthesis, purification, and validation of analytical standards such as dioxins, furans, PAH's, acetylated and methylated phenols, phenoxy herbicides as required by MOE laboratories and not available commercially.
- Development of methods for validating standard concentrations.
- Development of protocols for preparation, storage and use of analytical standards (long term stability of standard solutions). Including ampouling, freezing, storage under argon, or other inert gas.
- Development of certified reference materials such as soil, sediment, sludges, industrial effluent, biota.

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF
ANALYTICAL TECHNIQUES

ISSUE: AN05

Expert system applications to analytical processes.

Type of Research Needed:

- Design IBM compatible systems using a rule based process to extract information to aid in the processing of large amounts of data.
- Development of expert systems to aid in troubleshooting analytical instrumentation: GC, GC-MS, HPLC, ICP-MS, etc.

ANALYTICAL METHOD DEVELOPMENT: REFINEMENT OF
ANALYTICAL TECHNIQUES

ISSUE: AN06

Advanced data interpretation processes.

Type of Research Needed:

- Design multivariate statistics-based process to extract information to aid in the processing of large amount of data.
- Use of partial least square method to obtain valuable information from undefined data.
- Development of pattern recognition methods to extract information from complex data sets.

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN07

Broad spectrum scanning of contaminants in drinking, surface and wastewaters.

Type of Research Needed:

- Development of ICP-MS, GC-microwave plasma emission spectroscopy, ion specific mass detector, biological on-line monitoring tests for screening trace metals in a variety of environmental wastewaters.
- Development of Fourier Transform ICP and ion chromatography/FT-ICP for the identification and monitoring of trace metals in a variety of environmental samples.

*See also:

Water Quality Research:

Wastewater Treatment- WA08

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN08

Analytical method development to support MISA.

Type of Research Needed:

- Evaluation of the possible interferences in the analysis of inorganic parameters in aqueous wastes from industrial operations.
- Investigation of matrix modification techniques to enhance specific analyte detectability and response.
- Development of methodology for quantifying trace contaminants (volatiles especially) associated with liquid and solid fractions of sludges.
- Development of standard protocols for sediment and biota tissue analysis of resin and fatty acids and speciated phenols related to pulp and paper.
- Development of flowthrough field analysis of colour and fluorescence in pulp and paper mill effluents for rapid detection to identify the extent of impact of mill discharges.
- Screening of extraction techniques for recovery efficiency especially in sludges.
- Development of automated cleanup procedures required for sewage sludge analysis.

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN09

Large volume sampling systems for preconcentration of low level toxic contaminants.

Type of Research Needed:

- Extension and testing of membrane/resin technology for a comprehensive range of trace organics. Development of rugged high flow field sampling systems.
- Evaluation of the capacity of membrane/resin system to recover total organic loading from waters and waste waters.
- Evaluation of the effect of suspended particulate on the distribution and collection of organics in water.
- Development of resin columns for single step extraction and clean-up at present method detection limits.
- Extension of development of single step extraction/clean-up columns to allow lower detection limits.

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN10

Surrogate parameters for water monitoring.

Type of Research Needed:

- Development, improvement and evaluation of effectiveness of detection limits of surrogate parameters and correlation with specific and group toxic compounds in drinking and waste waters.
- Development of pattern recognition techniques based on flavour profile techniques for identifying taste and odour problems.

*See also:

Water Quality Research:

Wastewater Treatment - WA01,
- WA02, - WA05

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN11

Sampling protocols for contaminants in surface drinking waters, industrial effluents and sludges.

Type of Research Needed:

- Determination of significance of sampling protocols on chemical and microbiological analytical data.
- Development/evaluation of samplers for collection of liquid/solid samples for purgeable and extractable organic analysis.
- Evaluation of sampling and preservation techniques for purgeable and extractable organic analysis.
- Investigation of non-open sample collection methodologies to avoid atmospheric contamination of groundwater sampling and degassing of dissolved gases (N₂, CO₂, etc.)
- Solid phase extraction of organics in water samples.

ANALYTICAL METHOD DEVELOPMENT: DRINKING, SURFACE,
WASTEWATER ANALYSIS

ISSUE: AN12

Analytical method development to support Reg. 309.

Type of Research Needed:

- A thorough validation of Canadian Extraction Procedure for metals and anions.
- Development of tests for reactive wastes (eg., wastes containing cyanide or hydrides, alkaline solutions).
- Development of laboratory tests for ignitable wastes (eg., oils).
- Sensitive method for the determination of Nitro-tri-acetic acid (NTA).

ANALYTICAL METHOD DEVELOPMENT: LANDFILL LEACHATE, EFFLUENT,
HAZARDOUS WASTE ANALYSIS

ISSUE: AN13

Tiered testing of ground-water for landfill investigations.

Type of Research Needed:

- Development of a tiered testing protocol including validation of sample integrity for groundwater contaminant analysis.
- Ruggedness testing and development/refinement of analysers for wastewaters, landfill leachates groundwater.

*See Also:

Liquid & Solid Waste Research: Groundwater Contamination
- LS13

ANALYTICAL METHOD DEVELOPMENT: LANDFILL LEACHATE, EFFLUENT,
HAZARDOUS WASTE ANALYSIS

ISSUE: AN14

Analytical method development to assess leaching potential of specific wastes for hazardous waste classification.

Type of Research Needed:

- Development of serial leaching procedures for specific wastes to determine the effect on contaminant concentration.
- Development of a simplified procedure to determine the effect of long term (serial) leaching.
- Investigation of alternate leaching procedures and development of procedures and protocols suitable for volatile and non-volatile organics.

*See also:

Liquid & Solid Waste Research: Waste Handling

- LS03

Landfill Technology

- LS10

ANALYTICAL METHOD DEVELOPMENT: AIR & WATER ANALYSIS

ISSUE: AN15

Isotope ratios and isomer distribution patterns techniques as applied to source tracking of pollutants.

Type of Research Needed:

- By applying advanced analytical techniques such as computerized GC-MS, FTIR, GC-MS, XRD, ICP-MS;
- Development of methods for comparing profiles of organics/inorganics for generic identification for sample types such as coal tar.
- Comparison and relationship to source of isomer distribution patterns for compounds such as PCB, toxaphene, dioxins.
- Investigation of relationship of emission patterns to sources using surrogates and isotope ratios of elements, such as lead (Pb).
- Evaluation of the relationship of naturally occurring isotopic fractionation mechanisms to sources.
- Evaluation and relationship to sources of isotopic ratios in elements found in coal, lead, and zinc deposits etc. for various geological regimes (Cambrian, Paleozoic, Mesozoic etc.)

*See also:

Air Quality Research:

Contaminant Effects/Toxicology/-
Fates - AR02

Water Quality Research:

Managing Non-point sources of
Pollution

- WA09

Contaminant Fate & Transport
Processes in Aquatic System

- WA18

Liquid & Solid Waste Research:

Landfill Technology - LS13

ANALYTICAL METHOD DEVELOPMENT: AIR ANALYSIS

ISSUE: AN16

Sampling and analysis of gaseous and particulate emissions in air.

Type of Research Needed:

- Development of broad spectrum screening methods to extend the range of compounds monitored to include odorous compounds such as mercaptans and amines and to provide a more rapid and cost effective approach to analysis of organic air pollutants.
- Development of calibration standards for trace organic compounds and procedures for field calibration of complex mixtures.
- Study of high resolution and multidimensional (high resolution) GC in connection with EI-MS and FTIR and development and expansion of the appropriate data base for real time mobile monitoring.
- Development of broad spectrum screening methods to extend the range of PAH currently monitored with emphasis on specificity and increase the cost-effectiveness of methods for PAH, nitro PAH and CDD/CDF.
- Development of improved sampling methods to determine the vapour/particulate distribution of PAH and CDD/CDF in ambient air.
- Automation of sample preparation for air samples.
- Development of cryogenic purge and trap techniques for odorous problems in water.
- Development of routine analytical methods for the use of cannister sampling for volatile organics.

*See Also:

Air Quality Research:

Sources/Inventories - AR04

Instrument Development &

Application - AR06

Liquid & Solid Waste Research: Waste Handling - LS03

ANALYTICAL METHOD DEVELOPMENT: AIR ANALYSIS

ISSUE: AN17

Biological and microbiological procedures.

Type of Research Needed:

- Development of laboratory protocols for recovery, identification, and enumeration of pathogenic organisms (virus, bacteria, protozoa).
- Development of field methods for pre-concentration of viruses.
- Development of fluorescent antibodies to an antigen common to E. coli (as many serotypes as possible) and to an antigen common to group D enterococci.
- Development of image analyser and computer to automatically count and compute the concentration of fecal indicator bacteria in water and sediment.
- Further modification of the above techniques for the detection of pathogenic bacteria such as; Salmonella, Campylobacteria etc.
- Development of techniques for assessing sources eg., human vs non-human, of bacterial contamination.
- Development of alternative medium for M-ENDO LES Agar for the enumeration of total coliforms in drinking water samples.

*See Also:

Air Quality Research:

Water Quality Research:

Risk Management - AR07

Impacts of Pollutant Discharges

on Aquatic Systems - WA22

Drinking Water- WA23, - WA24

Wastewater Treatment - WA01

ANALYTICAL METHOD DEVELOPMENT: BIOLOGICAL ANALYSIS

ISSUE: AN18

Genotoxicity testing.

Type of Research Needed:

- Development of in-situ test systems to identify the presence of genotoxic compounds or conditions (mixture effects) in the environment.
- Development of laboratory screening tests that can be quickly and economically carried out on environmental samples.

ANALYTICAL METHOD DEVELOPMENT: BIOLOGICAL ANALYSIS

ISSUE: AN19

Development of field analytical techniques for environmental contaminants.

Type of Research Needed:

- Development of field monitoring equipment for specific chemical contaminants.
- Development of field analytical techniques that provide data on environmental contaminants that are comparable to the data produced by laboratory techniques.

ENVIRONMENTAL SOCIO-ECONOMIC RESEARCH NEEDS

ENVIRONMENTAL SOCIO-ECONOMIC RESEARCH

With the onset of environmental awareness in North America in the late 1960's, environmental protection was felt by many to transcend economic constraints and considerations. Indeed, economic considerations were perceived by environmental advocates to be impediments to the achievement of environmental goals. Because environmental resources and human health threatened by pollutants were considered to be priceless by many people, none of the statutes that were enacted at that time made any mention of economic implications or justification. However, it was soon discovered that resources to implement environmental protection programs were limited and trade-offs had to be made among programs, timing and achievements. Economic principles provide framework and criteria for making these trade-offs.

By the early 1980's, the role of economics in the Ministry was well established. However, nearly every issue that was investigated raised new questions and identified important information gaps. It was then that a Socio-Economic component was added to the Environmental Research Program administered through the Research Advisory Committee (RAC). Since the inception of this component, the RAC has supported projects on the economics of hazardous waste transport, biotechnology policy, methods to value non-market goods and services, determinants of participation in solid waste source separation and the costs of advanced wastewater treatment methods for metal finishing and plating processes.

Topics for research on economic environmental linkages are listed under six primary issues or subject areas:

- quantification and valuation of pollution damages, risks and disruptions;
- determination of the costs of pollution abatement and environmental protection and their implications;
- development of evaluation tools and their application to proposed policies or programs;
- assessments of industries and businesses which develop and manufacture environmental protection technologies, equipment, products and services;
- social implications of environmental contaminants and their control;
- development and testing of forecasting, simulation and optimization models.

There is a particular need for application of risk assessment methodologies, valuation of risk reductions and methods to develop reliable inventories of resources at risk. The key factors which motivate private sector decisions regarding technology choice and

environmental program implementation are also of interest. Information is needed about technologies for groundwater protection and cleanup and their costs.

Insights about the factors that could allay citizens' fears and anxieties regarding the location of solid waste incinerator, processing and disposal sites are needed as well as research that will help implement composting, source separation and other waste reduction practices.

Finally, empirical studies which show how measurable pollution discharges or environmental quality conditions actually affect human uses, activities, expenditures and perceptions are especially needed for use in regulation development and evaluation activities.

It is clear that there are socio-economic aspects concerning virtually every environmental problem or issue. It is also clear that, in the context of the Ministry's RAC program, the socio-economic component provides the opportunity to integrate widely disparate bio-physical, social and economic data into policy relevant frameworks.

ENVIRONMENTAL SOCIO-ECONOMIC RESEARCH

Issues of Immediate Concern

ISSUE:

- SE01 Quantification and Valuation of Pollution Damages, Risks and Disruptions and the Benefits of Environmental Protection and of Sustainable Development
- SE04 Assessment of the Characteristics, Structure and Performance of Environmental Protection Related Industries and Businesses
- SE05 Social Implications of Environmental Contaminants and their Control

SUMMARY OF ENVIRONMENTAL SOCIO-ECONOMIC RESEARCH ISSUES

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
<u>SOCIO-ECONOMIC RESEARCH</u>			
Environmental Damages and Benefits	SE01 Quantification and valuation of pollution damages, risks and disruptions and the benefits of environmental protection and of sustainable development.	98	AR01/8 WA14/33 WA22/42 WA23/43 WA27/47 LS04/56 LS10/62 LS11/63 MM02/110 MM04/112 MM05/114
Costs of Controls and Mitigation	SE02 Determination of the costs and other economic consequences of environmental protection and pollution and pollution abatement activities.	100	AR02/9 AR04/11 AR05/12 AR07/14 WA01/20 WA02/21 WA03/22 WA04/23 WA06/25 WA13/32 LS02/54 LS03/55 LS05/57 LS06/58 LS07/59
Evaluation Tools and Applications	SE03 Development and application of procedures and methods to evaluate policies, programs and projects.	101	WA04/23 WA07/26 WA14/33 WA23/43 LS05/57 LS06/58
Environmental Protection Industry	SE04 Assessment of the characteristics, structure and performance of environmental protection related industries and businesses.	102	AR07/14 LS06/58

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES AND PAGE NO.
Social (Non-Economic) Implications	SE05 Social implications of environmental contaminants and their control.	103	MM04/112
Enviro-Economic Modelling	SE06 Development and testing of forecasting simulation and optimization models.	104	AR02/9 AR03/10 WA14/33 WA18/37 WA26/46 WA27/47 MM01/109 MM02/110 MM03/111 MM04/112 MM05/114

ENVIRONMENTAL SOCIO-ECONOMIC
RESEARCH:

ENVIRONMENTAL DAMAGES AND BENEFITS

ISSUE: SE01

Quantification and valuation of pollution damages, risks and disruptions and the benefits of environmental protection and of sustainable development.

Type of Research Needed:*

- Develop and apply methods to determine the relative importance people place on different types of risk (including voluntary risks and both short and long-term risks) and how much people value reductions in such risks.
- Develop estimates of the specific short and long term costs and expenditures caused by environmental effects and damages (eg. health care, lost wages, corrosion losses, etc.)
- Conduct behavioural experiments to determine individuals' actual willingness-to-pay or willingness-to-accept-compensation values for specific environmental features or attributes.
- Compare the results of different valuation methodologies for similar non-market environmental goods or activities.
- Develop quantitative relationships between water quality measures/indicators and uses of water bodies for swimming, fishing, boating and other recreational activities.
- Develop and apply methods to produce inventories of various resources at risk.
- Develop and test procedures to quantify various types of environmental damages and to assign measures of relative importance, taking into account reversability of damages.
- Determine the relative importance that people place on odours from urban and/or rural sources and the value people attribute to reductions in odours.
- Conduct field tests and evaluate the importance that people place on the extent, volume and type of noise arising from outside sources that appear to impact adversely on the right to enjoy one's property in peace.
- Quantify and estimate the values of the beneficial (crop productivity, reductions in annoyance and health risk, etc.) and adverse (increased risk of contamination and health effects, damages to wildlife, etc.) effects of pesticide use.

continued. . .

ENVIRONMENTAL SOCIO-ECONOMIC
RESEARCH:

ENVIRONMENTAL DAMAGES AND BENEFITS

ISSUE: SE01 (continued)

- Develop estimates of damages due to ground water contamination and the costs and benefits of its prevention or mitigation including the consequences of change in sustainable rates of water use.
- Adapt or develop human health and risk dose-response relationship functions for toxic-hazardous waterborne and airborne compounds to predict and quantify damages from specific pollutants, economic activities or development projects, taking into account both short-term and long-term consequences.
- Determine the external economic effects of waste disposal and processing sites with specific reference to likelihood and timing.
- Adapt or develop human health and risk dose-response relationships for toxic substances to predict and quantify the beneficial consequences that result from abatement and protection activities.
- Document the private benefits (e.g. recovered by-products, cost reductions, raw material and energy savings, product quality improvements, etc.) of industrial abatement technologies, systems, or programs and the implications of such benefits on investment and growth.
- Compare methods of valuing marginal changes with those for valuing extinction, all or nothing situations or catastrophes.
- Examine the characteristics of the markets for secondary materials and determine the long term potential for such markets.

*See Also:

Air Quality Research:

Contaminant Effects/Toxicology/Fates
- AR01

Water Quality Research:

Impacts of Pollutant Discharges on
Aquatic Systems - WA22
Drinking Water - WA23

Effects of Acidic Deposition and the
Long Range Transport of Contaminants
- WA27

Liquid and Solid Waste
Research:

Landfill Technology - LS11

Multimedia Contaminants and
Biotechnology Research:

Risk Identification and Assessment
Methods - MM02

ENVIRONMENTAL SOCIO-ECONOMIC
RESEARCH:

COSTS OF CONTROLS AND MITIGATION

ISSUE: SE02

Determination of the costs and other economic consequences of environmental protection and pollution abatement activities.

Type of Research Needed: *

- Develop abatement cost functions for particular pollutants in specific industries which can be used in future studies and assessments.
- Estimation of the costs of controlling air emissions from fuel burning by households and commercial units.
- Cost effectiveness of monitoring strategies.
- Analysis of demand characteristics and price elasticities for pollution abatement systems, services and equipment.
- Determine the motivating factors for industrial and municipal decision-makers with respect to abatement/environmental protection programs including any perceived tradeoffs between current and future welfare.
- Compare the costs and other implications of "up front" mine rehabilitation measures with post closure clean-up practices.
- Document the distribution of environmental protection costs.
- Analysis of the distributional impacts of abatement policy initiatives on firms, industry, and municipalities.

*See Also:

Air Quality Research:	Contaminant Effects/Toxicology/- Fates- AR02 Sources/Inventories - AR04 - AR05 Control and Remedial Technology - AR07
Water Quality Research:	Wastewater Treatment- WA01 - WA02 - WA03 - WA04 - WA06 Managing Non-Point Sources of Pollution - WA13
Liquid and Solid Waste Research:	Waste Handling- LS02 - LS03 Waste Reduction - LS05 - LS06 Landfill Technology - LS07

ENVIRONMENTAL SOCIO-ECONOMIC
RESEARCH:

EVALUATION TOOLS AND APPLICATION

ISSUE: SE03

Development and application of socio-economic procedures and methods to evaluate environmental policies, programs and projects.

Type of Research Needed:*

- Conduct benefit-cost analyses of specific environmental protection programs, sustainable development projects or activities.
- Design and test economic incentive instruments to achieve environmental policy objectives.
- Application of linear programming techniques to identify cost-effective abatement strategies.
- Determination of polluters' responses and behaviour to different regulatory instruments and approaches.
- Compare non-economic evaluation techniques with benefit-cost analysis. Will such methods as the Judgmental Impact Matrix, forms of social impact assessment, risk assessments or net energy analysis yield the same conclusions as benefit-cost analysis given the same input data?
- Develop criteria for evaluating and making decisions concerning conservation and/or enhancement of productive capability, environmental quality, and renewable resources accruing over extremely long periods of time in contrast to conventional approaches to discounting future benefits.
- Assess theoretical foundations of benefit-cost analysis, propose alternative ethical paradigms and test with case studies.
- Develop environmental preference and environmental quality of life indices.
- Develop an operational and measurable definition of sustainable development.

***See Also**

Water Quality Research: Wastewater Treatment - WA04, WA07
Drinking Water - WA23
Liquid and Solid Waste Research: Waste Reduction - LS05, LS06

ENVIRONMENTAL SOCIO-ECONOMIC
RESEARCH:

ENVIRONMENTAL PROTECTION INDUSTRY

ISSUE: SE04

Assessment of the characteristics, structure and performance of environmental protection related industries and businesses.

Type of Research Needed:*

- Development and testing of environmental auditing procedures.
- Determination of price elasticities and other factors which affect the demand for secondary materials.
- Determinants of innovation in pollution abatement/ resource recovery technology.
- Exploration of the factors and experience which concern the development and choice of pollution control and prevention technologies.
- Determination of the economic dimensions, structure and performance of firms and industries which manufacture and sell pollution control equipment and supplies or which supply environmental protection services.
- Assessment of the economic implications of biotechnology applications.
- Examine the activities related to waste exchange and waste valuation, and assess how such transactions relate to waste management policy initiatives.

*See Also

Air Quality Research:

Control and Remedial Technology
- AR07

Liquid and Solid Waste
Research:

Waste Reduction - LS06

ENVIRONMENTAL SOCIO-ECONOMIC SOCIAL (NON-ECONOMIC) IMPLICATIONS
RESEARCH:

ISSUE: SE05

Social implications of environmental contaminants and their control

Type of Research Needed:

- Development of a more comprehensive understanding of the social and psychological impacts of individual and community exposure to environmental contaminants, particularly in terms of:
 - . the identification of factors that determine such impacts and processes by which they are manifested; and
 - . the development and evaluation of strategies for predicting, preventing and/or mitigating social and psychological impacts.
- Identification of factors which determine public perceptions of, and responses to, voluntary and/or involuntary risks associated with environmental contaminants.
- Determination of emitters' or dischargers' perception of risk and/or costs due to potential prosecutions or other adverse consequences of non-compliance compared with the statistical experience of having violations detected, prosecuted, convicted and fined.
- Development and evaluation of approaches for communicating information about environmental hazards and risks to the public.
- Empirical evaluation of different approaches to consulting the public on environmental issues.
- Development of new approaches or methodologies for predicting the social impacts of changes (improvements or decrements) in environmental quality.
- Develop and estimate measures of the social effects of waste disposal and processing sites.
- Determine the factors (economic, social, cultural, locational, etc.) that influence attitudinal and behavioural change towards waste reduction or elimination in private consumption.

***See Also:**

Multimedia Contaminants and
Biotechnology Research:

Risk Identification and Assessment
Methods - MM02

ENVIRONMENTAL SOCIO-ECONOMIC RESEARCH:

ENVIRO-ECONOMIC MODELLING

ISSUE: SE06

Development, testing, and application of forecasting simulation and optimization models.

Type of Research Needed: *

- Comparisons of statistical and economic techniques and models to forecast:
 - . control technology changes;
 - . contaminant discharges/emissions; and
 - . spills.
 - Development and testing of models which link and integrate economic activities with environmental systems.
 - Development of bio-economic models and software to simulate and evaluate the consequences of possible pollution scenarios.
 - Development of models to analyze economic and financial impacts of environmental requirements at the level of the firm, industry or the provincial economy.
 - Development of a model to ascertain the trade-offs and levels of uncertainty attached to various adverse environmental occurrences. What can be considered an acceptable risk.
 - Empirical application of models which examine the economic risks associated with accidental exposure to toxics through the containment and/or clean-up of hazardous waste spillage, leachate, or emission.

*See Also:

Air Quality Research: Contaminant Effects/Toxicology/Fates
- AR02

Water Quality Research: Atmospheric Processes - AR03
Contaminant Fate and Transport Processes
in Aquatic Systems - WA18
Effects of Acidic Deposition - WA26

**MULTIMEDIA CONTAMINANTS
AND BIOTECHNOLOGY
RESEARCH NEEDS**

MULTIMEDIA CONTAMINANTS AND BIOTECHNOLOGY RESEARCH

Multimedia chemicals can be defined as those chemicals, which, when released to the environment, will partition so that the concentrations are significant in all of the important environmental compartments or media - air, water, soil and biota. Such chemicals are ubiquitous because they persist, are discharged continually, or have a tendency to bioaccumulate. Examples of such contaminants are persistent organics such as dioxins and dibenzofurans, and PCBs; persistent metals such as arsenic, cadmium and lead; or ubiquitous contaminants such as polynuclear aromatic hydrocarbons.

As a result of its significant distribution into several compartments, all human exposure routes for a multi-media chemical are important and it is not possible to restrict consideration of toxic effects to exposures from a single medium. To ensure that an acceptable level of exposure from all environmental sources is not exceeded, it is necessary to develop environmental standards using an integrated multimedia approach.

The research needs for multimedia contaminants cover three main categories:

- 1) risk identification and risk assessment;
- 2) exposure assessment; and
- 3) toxicology.

These needs overlap the research needs for air and water quality and, to lesser extent, for analytical methods. At this time, the emphasis for multimedia contaminants is primarily on human health effects.

1. Risk identification involves a preliminary determination of the toxicity and exposure potentials of contaminants and their characterization with respect to the degree of hazard they exhibit. Risk assessment for a multimedia contaminant involves the evaluation of the toxic effect and dose-response relationships for all possible receptors, including humans, and the consideration of the exposure potential based on exposure assessments.
2. Exposure assessment requires knowledge of the transport and environmental fate of chemicals in air, water and soil after emission from a source; knowledge of the concentration - measured or modelled - of chemicals in all media, including food and indoor air; and knowledge of the amounts that humans and organisms absorb into their bodies. This last aspect involves the development of methods, models and guidelines for estimating the exposure to multimedia contaminants.

3. Toxicology involves the determination of adverse effects of multimedia contaminants on living organisms, including man. This can be achieved for human health effects through epidemiological studies of human populations and extrapolations from animal studies. The use of animal studies requires the development of models, methods and guidelines for the extrapolations to humans. The adverse effects include acute and chronic endpoints, including cancer and such non-cancer endpoints as neurotoxicity and reproductive effects. In addition, this area considers effects of environmental pathogens on human health.

It should be recognized that many of the research projects in toxicology are costly and multi-year. Researchers are encouraged to explore co-funding from other federal, provincial or other agencies that also have research interests in toxicology before applying for funding from the Ministry of the Environment.

Biotechnology is a new area of concern for the Ministry of the Environment. Biotechnology involves the application of science and engineering to the direct and indirect use of living organisms and parts or products of organisms to provide goods and services. The research issues for biotechnology are under development.

MULTIMEDIA CONTAMINANTS AND BIOTECHNOLOGY RESEARCH
Issues of Immediate Concern

ISSUE:

- MM01 Development of Methods for Identifying Chemicals that are Hazardous
- MM02 Development of Methods and Guidelines for Assessing the Risk to Man and the Environment of Hazardous Multimedia Chemicals
- MM03 Improved Understanding of Environmental Fate and Transformations of Multimedia Chemicals and Information on Environmental Concentrations of such Chemicals
- MM04 Development of Methods and Guidelines for Multimedia Exposure Assessment and Reducing Uncertainties in the Estimation of Multimedia Exposures
- MM05 Studies of Adverse Effects of Multimedia Chemicals on Human Health

SUMMARY OF MULTIMEDIA CONTAMINANTS
AND
BIOTECHNOLOGY RESEARCH ISSUES

RESEARCH CATEGORY	ISSUES	PAGE NUMBER	RELATED ISSUES
<u>MULTIMEDIA CONTAMINANTS</u>			
Risk identification and assessment methods	MM01 Development of methods for identifying chemicals that are hazardous. MM02 Development of methods and guidelines for assessing the risk to man and the environment of hazardous multimedia chemicals. MM03 Improved understanding of environmental fate and transformations of multimedia chemicals and information on environmental concentrations of such chemicals.	109 110 111	SE01/98 SE05/103 AR02/9 AR06/13 WA08/27 WA17/36 WA18/37 WA19/38 WA27/47 WA28/48 AN01/73 AN15/87 AN16/88
Exposure assessment	MM04 Development of methods and guidelines for multimedia exposure assessment and for reducing uncertainties in the estimation of multimedia exposures.	112	
Toxicology	MM05 Studies of adverse effects of multimedia chemicals on human health.	114	

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH:

RISK IDENTIFICATION AND
RISK ASSESSMENT METHODS

ISSUE: MM01

Development of methods for identifying chemicals that are hazardous. This involves the identification of previously undetected chemicals in all environmental media and the preliminary assessment of the potential hazard of these chemicals to selected biota including humans.

Type of Research Needed:*

- Development and application of structure-activity relationships for the rapid assessment of the toxicity of new chemicals.

***See Also:**

- Analytical Method Development: Refinement of Analytical Techniques - AN01
Environmental Socio-Economic Research: Enviro-Economic Modelling - SE06

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH:

RISK IDENTIFICATION AND
RISK ASSESSMENT METHODS

ISSUE: MM02

Development of methods for assessing the risk to man of hazardous multimedia chemicals.

Type of Research Needed:*

- Development of risk assessment methods for protection of air, water and soil quality as it applies to human health effects.
- The development of methods to integrate information on pollutant sources, fate and transport and exposure with data on human health in order to assess the overall risk posed by a pollutant or a group of pollutants to man.
- Risk assessment of mixtures. Both the methodology for risk assessment on mixtures and the data necessary for evaluating mixtures need to be developed.
- Development of risk assessment guidelines for cancer and noncancer endpoints by identifying and addressing the significant uncertainties in risk assessment procedures, including consideration of reversibility and weight-of-evidence schemes.

*See Also:

Environmental Socio-Economic
Research:

Environmental Damages and
Benefits - SE01
Social (Non-Economic)
Implications - SE06

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH:

RISK IDENTIFICATION AND
RISK ASSESSMENT METHODS

ISSUE: MM03

Improved understanding of environmental fate and processes of multimedia chemicals and information on concentrations of such chemicals in the environment. This has two components:

- Environmental processes and fate: to understand how pollutants are transported and modified as they move through soils, ground and surface waters and the atmosphere.
- Integrating monitoring data by identifying and quantifying pollutants in the environment which contribute to human exposure by all pathways.

Type of Research Needed:*

- Identification and quantification of the source contribution to the environmental mixture using "Source Markers".
 - Collection of Ontario-specific data to fill information gaps on multimedia concentrations of various contaminants and mixtures, including quantification of emissions from non-standard sources (e.g. fugitive emissions, non-point sources).
 - Structure-activity relationships for rapid assessment of environmental fate of new chemicals.
 - Structure of sufficient information to establish exposure standards.
-

*See Also:

Air Quality Research:

Contaminant Effects/Toxicology /Fates - AR02

Instrument Development and Application - AR06

Water Quality Research:

Managing Non-Point Sources of Pollution - WA08

Contaminant Fate and Transport Processes in Aquatic Systems - WA17, WA18, WA19

Effects of Acidic Deposition and the Long Range Transport of Contaminants - WA27, WA28

Analytical Method Development:

Refinement of Analytical Techniques - AN01

Air and Water Analysis - AN15

Air Analysis - AN16

Environmental Socio-Economic Research:

Enviro-Economic Modelling - SE06

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH:

EXPOSURE ASSESSMENT

ISSUE: MM04

Development of methods and guidelines for multimedia exposure assessment and for reducing the uncertainties in the estimation of multimedia exposures. This includes both total and target organ exposures.

Type of Research Needed*

- Development of multi-pathway exposure models, including dispersion modelling, receptor level modelling and intermedia modelling for both point and non-point sources. Dosimetry models for oral, dermal and inhalation routes (total and target organ doses).
- Effective exposure monitoring using biochemical, genetic and immunologic techniques as indicators of human and target organ exposures (markers).
- Effective exposure monitoring by measuring tissue levels.
- Improved models to extrapolate animal exposure data to humans.
- Bioavailability of toxicants bound to air-suspended particles, sediments, soil and dust or various components of food.
- Modelling the effect of the route of exposure to enhance the understanding of how a compound or mixture may have different potency, site of action and perhaps even a mechanism of action, depending on the route.
- Quantification of the uptake of environmental contaminants from food consumed by humans, including the uptake of contaminants by plants and animals from all media, the effects of processing, preservation and packaging of foods and the effect of the final preparation of foods prior to consumption by humans.

(Cont'd)

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH

EXPOSURE ASSESSMENT

ISSUE: MM04 (Cont'd)

- Elucidation of environmental pathways for transfer of contaminants into the food chain for humans.

See Also:

Environmental Socio-Economic
Research:

Environmental Damages and
Benefits - SE01
Social (Non-Economic)
Implications - SE05
Enviro-Economic Modelling
- SE06

MULTIMEDIA CONTAMINANTS AND
BIOTECHNOLOGY RESEARCH:

TOXICOLOGY

ISSUE: MM05

Studies of adverse effects of chemicals on human health to support standard setting activities. The adverse effects include cancer and non-cancer effects such as neurotoxicity and reproductive effects.

NOTE: It should be recognized that many of the research projects in toxicology are costly and multi-year. Researchers should explore co-funding from other federal, provincial or other agencies that also have research interests in toxicology before applying for funding to the Ministry of the Environment.

Type of Research Needed*

- Testing of priority compounds or mixtures with carcinogenic properties in standardized long-term in vivo assays.
- The effect of exposure (dosing) schedule on the toxicity of carcinogenic compounds and mixtures.
- Establish target equivalence of dose for contaminants between man and experimental species.
- Research on toxic effects other than cancer (e.g. neuro-toxicity, immunotoxicity, reproductive toxicity) caused by pollutants in air, water and food and other exposure routes.
- Studies to establish criteria for the protection of human health from contaminants in sport fish and from waterborne pathogens.
- Determination of the relationship between monitoring data, human health and various specific air, water and soil pollution problems.
- Determination of effective dose of major waterborne pathogens on humans.
- Evaluation of acute and chronic effects of air, water and soil pollutants on human health.

*See Also

Environmental Socio-Economic
Research:

Environmental Damages and
Benefits - SE01
Enviro-Economic Modelling
- SE06

APPENDIX

Approval and Funding Statistics 1989-90

The table below summarizes the statistics of proposal approval in each of the research areas:

<u>Research Area</u>	<u># Received</u>	<u># Approved</u>	<u>%</u>
Air Quality	17	9	53
Water Quality	76	20	26
Liquid and Solid Waste	15	5	33
Analytical Method Development	28	6	21
Environmental Socio-Economics	6	3	50
TOTAL	142	43	30

These statistics cover only proposals approved and initiated in 1989-90. A significant amount of project work funded was carried over from previous years (1987-88 or 1988-89).

It should be noted that the approval rate was higher than normal in 1989-90 and compares to a "normal" rate of around 20%.

The following tabulation summarizes project cost information in FY 1989-90.

Mean funding per project	\$45,000
Range of one-year project costs	\$20,000-\$100,000
Mean of full project funding (1 to 3 years)	\$75,000

Q U E S T I O N N A I R E

Thank you for reading and using the Research Needs document. Your comments and suggestions would be appreciated as we attempt to improve communication of Ministry research needs and priorities to the environmental research community. Please answer the following questions and add suggestions for improvement in the space provided. Return completed questionnaires using the address on the back.

Have you used Research Needs document YES _____ NO _____
before?

Have you previously been funded through the YES _____ NO _____
Research Advisory Committee?

Have you found this document to be in YES _____ NO _____
sufficient detail to guide you in selecting
a research topic?

Is the manner in which this document is YES _____ NO _____
organized (hierarchically according to
research area, category, issue and need)
useful?

Have you found the footnotes that YES _____ NO _____
cross-reference research issues to be useful?

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